

FORMALDEHYDE (GAS)

CAS No. 50-00-0

First Listed in the *Second Annual Report on Carcinogens*



CARCINOGENICITY

Formaldehyde (gas) is *reasonably anticipated to be a human carcinogen* based on limited evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in experimental animals (IARC V.29, 1982; IARC S.4, 1982; IARC S.7, 1987).

There is limited evidence for the carcinogenicity of formaldehyde in humans identified were limited (IARC S.7, 1987). Although excess occurrence of a number of cancers has been reported, the evidence for a possible involvement of formaldehyde is strongest for nasal and nasopharyngeal cancer. The occurrence of these cancers showed an exposure-response gradient in more than one study, but the numbers of exposed cases were often small and some studies did not show excesses. The nose and nasopharynx could come into direct contact with formaldehyde through inhalation. Excess mortality from leukemia and cancer of the brain was generally not seen among industrial workers, which suggests that the excess for these cancers among professionals is due to conditions other than formaldehyde. The slight excesses of cancer among professionals noted in several studies generally did not display the patterns of increasing risk with various measures of exposure (i.e., latency, duration, level, or cumulative) usually seen for occupational carcinogens. No other cancer showed a consistent excess across the various studies.

When administered by inhalation, formaldehyde induced squamous cell carcinomas of the nasal cavity in rats of both sexes (IARC V.29, 1982; IARC S.4, 1982; IARC S.7, 1987).

PROPERTIES

Formaldehyde is a flammable, colorless gas with a pungent, suffocating odor. It is miscible with water, acetone, benzene, diethyl ether, chloroform, and ethanol. Anhydrous gaseous formaldehyde is not available commercially. Most formaldehyde is sold as aqueous solutions, known as formalin, containing 30-56% formaldehyde with 0.5-15% methanol as a polymerization inhibitor. Typical specifications for 37% aqueous solutions are as follows: a maximum of 1.8% methanol or 5-8% methanol; a maximum of 0.03% acidity as formic acid; a maximum of 60 mg ash/kg; and a maximum of 1 mg iron/kg. Polymerization may also be inhibited by the addition of up to 100 mg/kg of stabilizers such as cellulose ethers or isophthalobisguanamine.

Formaldehyde is also available in the United States as its cyclic trimer, trioxane (CAS No. 123-63-7), and as paraformaldehyde (9002-81-7). Trioxane is a crystalline solid with a chloroform-like odor. It is easily soluble in water, alcohols, ketones, ether, acetone, chlorinated and aromatic hydrocarbons, and other organic solvents and slightly soluble in pentane, petroleum ether, and lower paraffins. In nonaqueous systems, trioxane readily converts to monomeric formaldehyde. Paraformaldehyde is available as a powdered or flaked product containing the equivalent of 90-93% formaldehyde, a maximum of 9% water, and a maximum of 0.03% acidity

as formic acid. It is soluble in fixed alkali hydroxide solutions, slowly soluble in cold water, more readily soluble in hot water with evolution of formaldehyde vapors, and insoluble in alcohol and ether.

USE

The primary uses for formaldehyde are for the production of urea-formaldehyde resins (generally about 25% of the formaldehyde produced), phenol-formaldehyde resins (20%), plastics (15%), and intermediates (22%). Most of the formaldehyde used for the production of intermediates is in the manufacture of acetylenic chemicals; smaller quantities are used in the production of pentaerythritol, hexamethylenetetramine, and urea-formaldehyde concentrates. The largest miscellaneous uses of formaldehyde are production of 4,4'-methylenedianiline (see Section III.B), 4,4'-methylenediphenyl diisocyanate, chelating agents, and trimethylolpropane. Urea-formaldehyde resins and phenol-formaldehyde resins are used primarily as adhesives in the manufacture of particle board, fiberboard, and plywood, and for molding, paper treating and coating, textile treating, surface coating, and foams for insulation (IARC V.29, 1982; Chem. Prod., 1983c; Chem. Eng. News, 1984b).

Additionally, formaldehyde has miscellaneous uses in agriculture for seed treatment and soil disinfection; as a reagent in analysis; to water- and grease-proof concrete and plaster; as a drying agent and preservative in cosmetics; in room deodorants; in disinfectants and fumigants; as a chemical intermediate for dyes, surface-active agents, and processing aids; in embalming as a preservative and hardener of tissues; in histopathology; as a biocide in drilling fluids; as a stabilizer in gasoline; in leather tanning; as a corrosion inhibitor in metal industries; in paper industries as a chemical intermediate for wet-strength and other paper treating resins; as a photographic film hardener; as a starch modifier; to modify fibers in textiles; and in wood preservatives.

Formaldehyde also has uses in human and veterinary medicine. It is used as a treatment for athlete's foot, in cough drops, skin disinfectants, mouthwashes, spermicide creams, as a disinfectant for vasectomies and root canals, and formerly to sterilize certain cysts prior to surgical removal. In veterinary medicine, it is used as an antiseptic and fumigant in the treatment of tympany, diarrhea, mastitis, pneumonia, and internal bleeding; in association with iodine it is used as a coccidiostat in chickens (IARC V.29, 1982).

PRODUCTION

Formaldehyde is consistently ranked among the top 50 highest volume chemicals produced in the United States each year by *Chemical and Engineering News*. Although separate production data are not available for anhydrous formaldehyde gas, they are for formaldehyde (37% by weight) where 8.1 billion lb were produced in the US in 1995 (Chem. Eng. News 1996).

The United States imported 23.9 million lb of formaldehyde and exported 23.5 million lb of the chemical in 1989 (USDOC Import, 1990; USDOC Export, 1990). In 1987, estimated imports were 11 million lb and exports were 19 million lb (Chem. Mark. Rep., 1989). Almost 9.5 million lb of formaldehyde, including solutions, were exported in 1985 and 1984 (USDOC Exports, 1986, 1985). More than 8.5 million lb of formaldehyde and formaldehyde solutions and nearly 4.9 million lb of paraformaldehyde were imported in 1985 (USDOC Imports, 1986). In 1984, over 10 million lb of formaldehyde and its solutions plus more than 5.1 million lb of paraformaldehyde were imported (USDOC Imports, 1985). Up to the mid-1980s, imports and

exports of formaldehyde have been nearly constant since 1981. Before that time, imports increased dramatically from "negligible" in the 1970s, whereas exports decreased dramatically from a peak of 127 million lb in 1975 (Chem. Prod., 1983c; IARC V.29, 1982).

EXPOSURE

The primary routes of potential human exposure to formaldehyde (gas) are inhalation, dermal contact, and ingestion. Most of the formaldehyde (gas) produced in the United States is synthesized from methanol in closed automated process systems. The risk of exposure during transportation and storage is likely to be minimal. Estimated emission levels from production plants range from 0.0004 to 2,500 $\mu\text{g}/\text{m}^3$, with a median exposure of 0.01 $\mu\text{g}/\text{m}^3$. EPA estimated that 27.7 million people living within 12.5 miles of point sources may possibly be exposed to low levels of formaldehyde. NIOSH estimated that 8,000 workers are possibly exposed to formaldehyde during direct production (NIOSH, 1976). Potential occupational exposure also occurs during the production of end products in which formaldehyde and its solutions are used, in the garment industry, during various preservation processes, and in laboratories. Health care professionals (e.g., pharmacists, physicians, veterinarians, dentists, nurses) may be exposed to vapors during the preparation, administration, or clean up of medicinal products. Patients who receive the medicines are directly exposed. Pathologists and histology technicians, and teachers and students who handle preserved specimens represent potential high-exposure groups. The National Occupational Exposure Survey (1981-1983) indicated that 551,795 workers, including 216,807 women, potentially were exposed to formaldehyde (NIOSH, 1984). The National Occupational Hazard Survey, conducted by NIOSH from 1972 to 1974, estimated that 1.6 million workers were exposed to formaldehyde in more than 60 industrial categories. Of these workers, about 57,000 were exposed for 4 hours or more per day. Nearly one-third (507,200) were engaged in medical and other health services, and another third (457,200) were in the following categories: chemicals and allied products, printing and publishing, paper and allied products, machinery (other than electrical), retail general merchandise, automotive dealers and service stations, eating and drinking establishments, and personal services (i.e., funeral services and crematories, photographic studios, and dry cleaning plants) (NIOSH, 1976; NIOSH 34, 1981). OSHA estimated that in the late 1980s, more than 2 million workers were potentially exposed to formaldehyde, and nearly one-half (941,000) were employed in the garment industry (Chem. Mark. Rep., 1987).

Consumers are possibly exposed to formaldehyde (gas) through its use in construction materials, wood products, textiles, home furnishings, paper, cosmetics, and pharmaceuticals. Automobile exhaust is a major source of formaldehyde in ambient air. Automobiles emit 610 million lb of formaldehyde each year. The ambient air in the United States possibly exposes the entire U.S. population of 230 million people to concentrations ranging from about 0.001 to 0.16 ppm. Two subpopulations with particularly high potential for formaldehyde exposure are the 2.2 million residents of mobile homes containing particle board and plywood (with an average exposure of 0.4 ppm formaldehyde) and the 1.7 million persons living in conventional homes insulated with urea-formaldehyde foam (with a potential average exposure of 0.12 ppm) (Chem. Eng. News, 1984e; IARC V.29, 1982; CHIP, 1979b). A recent study has found the prevalence of asthma to be related to emissions from newly painted indoor surfaces, particularly newly painted wood details. In addition, a significant increase in formaldehyde concentration (about 16 $\mu\text{g}/\text{m}^3$) was seen in houses with these details (Weislander et al., 1997). The suggestion that indoor formaldehyde may cause asthma-like symptoms was demonstrated when Nörback et al. (1995) found a significant relation between nocturnal breathlessness and the presence of the chemical in the bedroom. The mean concentration was 29 $\mu\text{g}/\text{m}^3$ in homes of subjects with the attack, versus 17 $\mu\text{g}/\text{m}^3$ in homes of those experiencing no such symptom.

Inadvertent production of formaldehyde from combustion sources also may contribute to these possible exposures. CPSC estimated that 159 million persons are possibly exposed to ambient air concentrations at maximum levels of $0.25 \mu\text{g}/\text{m}^3$. Additionally, cigarette smoke is reported to contain 20 to 90 $\mu\text{g}/\text{cigarette}$ of formaldehyde (Chem. Eng. News, 1984e; IARC V.29, 1982; CHIP, 1979b).

The chemical has a short half-life in air because it is degraded by photochemical processes; it is unstable in water. However, formaldehyde has been detected in municipal and industrial aqueous effluents, including those resulting from chemical, oil, and coal processing. Formaldehyde has been reported in rainwater, lake water, and some waterways. The Toxic Chemical Release Inventory (EPA) estimated that 21,256,884 lb of formaldehyde were released to the environment from 668 facilities that produced, processed, or used the chemical in the United States in 1996. The total releases were 11,419,200 lb to air, 320,003 lb to water, 114,406 lb to land, and 9,403,275 lb to underground injection wells. Approximately one-third (220) of the facilities, each releasing $> 10,000$ lb to the environment, accounted for 92.8% of the total air emissions. Thirty facilities, each releasing $> 100,000$ lb, accounted for 38.5% of these releases. Two Louisiana facilities that each discharged more than 1 million pounds of formaldehyde to the environment represented only 0.21% of the gross air release but accounted for 91.5% of the total injected underground (TRI96, 1998).

Exposure is also possible from plants, such as kidney beans and barley, which can absorb gaseous formaldehyde through their leaves. Maize leaves can form formaldehyde during photosynthesis. Other foods may also contain detectable amounts of formaldehyde either naturally or as a result of contamination. Formaldehyde is formed endogenously in mammals as a consequence of oxidative metabolism of many xenobiotics (IARC V.29, 1982).

REGULATIONS

Under the authority of the Federal Hazardous Substances Act (FHSA), CPSC requires warning labels on household products containing 1% or more of formaldehyde, warning that formaldehyde is a strong sensitizer. Under the authority of the Consumer Product Safety Act (CPSA), CPSC banned the use of urea-formaldehyde foam insulation in residences and schools. A U.S. Court of Appeals issued an opinion that would vacate the ban. After CPSC petitioned the court for a rehearing which resulted in no change in the decision, the Solicitor General was asked to appeal the decision to the Supreme Court. The Solicitor General did not appeal and the ban was vacated. CPSC studied the bioavailability and dermal penetration of formaldehyde from textiles. No penetration of the intact skin by formaldehyde was observed. Therefore, no further action, based on carcinogenic risk, was taken on the presence of formaldehyde in textiles. CPSC worked with the National Bureau of Standards and the Oak Ridge National Laboratory to develop models for indoor air levels of formaldehyde based on emission rates from pressed wood products and is now working with industry to pursue voluntary standards for these products.

EPA regulates formaldehyde under the Clean Air Act (CAA), Clean Water Act (CWA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Food, Drug, and Cosmetic Act (FD&CA), Resource Conservation and Recovery Act (RCRA), Superfund Amendments and Reauthorization Act (SARA), and Toxic Substances Control Act (TSCA). EPA has designated formaldehyde as a hazardous air pollutant, water pollutant, waste constituent, and inert ingredient of pesticide products. A reportable quantity (RQ) of 1,000 lb was established for formaldehyde under CWA, and EPA has lowered the RQ to 100 lb under CERCLA. General threshold amounts and a threshold planning quantity have been established under SARA. Under TSCA, EPA requires that manufacturers submit safety and health studies

related to exposure to urea-formaldehyde resins. FDA regulates formaldehyde as an indirect food additive under FD&CA. NIOSH has recommended a 0.1-ppm ceiling exposure concentration over a 15-minute period in the workplace. On July 2, 1984, the U.S. District Court for the District of Columbia ordered OSHA to initiate an assessment of formaldehyde to determine whether regulatory action should be taken. As a result of this assessment, on December 10, 1985, OSHA published a proposal to reduce the permissible exposure limit (PEL) to either 1 ppm or 1.5 ppm as an 8-hr time-weighted average (TWA) and to delete the ceiling and peak concentration limits. OSHA has reduced the PEL from 3 ppm to 1 ppm as an 8-hr TWA in air, and established a short-term exposure limit (STEL) of 2 ppm over a 15-minute period. OSHA is reevaluating the formaldehyde risk assessment; 29 CFR 1910.1048 (Hazard Communication) has been stayed in part until June 1990. OSHA regulates formaldehyde, however, under the Hazard Communication Standard (1910.1200) and as a chemical hazard in laboratories. Regulations are summarized in Volume II, Table B-65.